Near-Field Measurements of the KOUN WSR-88D

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ROC Hotline

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Background

This report represents the results of testing done on the National Weather Service's WSR-88D weather radar in Norman, OK. The purpose of the testing was to determine the electro-magnetic emissions of the WSR-88D at a range of 100ft to 1000ft for compliance with FCC Maximum Permissible Exposure (MPE) limits as detailed below and in reference 3. The pertinent parameters for this test are listed below.

Physical Characteristics	
WSR-88D Location for Testing	Norman, OK (KOUN)
WSR-88D Antenna Beam Center	90.62 ft (27.62 m) AGL
Emissions Characteristics	
WSR-88D Frequency	2705 MHz
WSR-88D Transmitter Peak Power	667 KW
WSR-88D Antenna	28 ft diameter, .98 degree beamwidth, 45 dBi gain
WSR-88D Volume Coverage Pattern	VCP 300
Maximum Exposure Levels	
FCC MPE for Public Exposure	1 mW/cm^2 over 30 minutes
FCC MPE for Occupational Environment	5 mW/cm^2 over 6 minutes

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Measurement Setup and Procedure

The near-field of the WSR-88D is defined to be the region from the antenna out to a range R where:

$$R = \frac{2D^2}{\lambda} \qquad (1)$$

For the case of KOUN, lambda is approximately 11 cm. By equation 1, the near-field extends to 1313 m (4307 ft).

As with all antennas, the WSR-88D wavefront forms within the near field of the antenna. Power density measurements within the near-field are extremely sensitive to position relative to the main beam. Measurements taken along an axis perpendicular to the wavefront will result in a large sample variance with some samples changing an order of magnitude within 20 feet. The typical attenuation contours that are present in the near-field can be seen in figure 1.

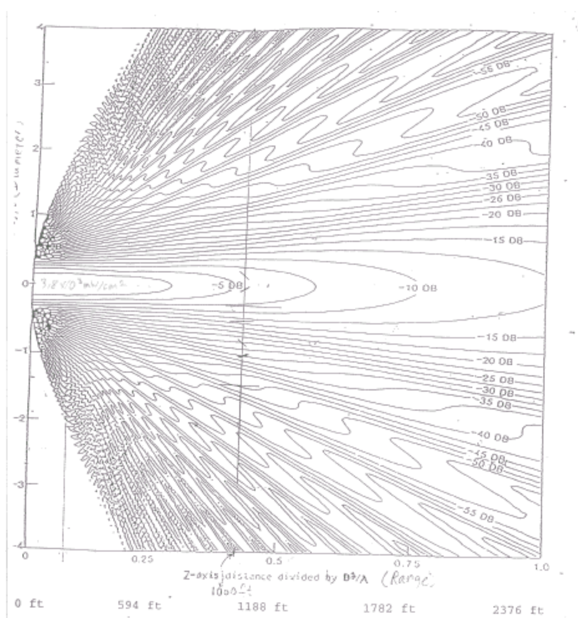

Figure 1 - Calculated Near-field Pattern [1]

For the purposes of this test, the effects of the near field antenna pattern would hinder the collection of data. To avoid this, measurements were not taken with the WSR-88D pointed along a specific axis. Instead, the WSR-88D was commanded to perform Volume Coverage Pattern (VCP) 300. This pattern is not used for operational weather data collection, but is reserved for maintenance use only. VCP 300 performs 2 elevations scans at 0.5 degrees. This is the lowest elevation cut taken operationally and therefore peak power density measurements from VCP 300 will match peak power density measurements taken under operational VCP's.

Measurements were taken using a standard gain horn antenna and a spectrum analyzer. The equipment was positioned at 100 ft intervals from the site for each measurement. The spectrum analyzer was set to peak hold mode and allowed to collect measurements for 3 minutes (the length of VCP 300). For this configuration, the spectrum analyzer is measuring the instantaneous peak power density at a given range from KOUN. As mentioned above, this is the same peak power density that would be seen under any VCP (operational or maintenance).

While the measurement setup excludes a number of error sources, it must be understood that power density measurements made in this manner are still subject to off-axis attenuation. As can be seen in figure 1, if the observation point is moved (decrease in tower height or increase in terrain elevation surrounding the site) the power density measurements will be effected. The correlation is not always intuitive or predictable. During the course of these measurements it was proven that the large variance in attenuation throughout the near-field does not guarantee that a decrease in the depression angle from the main beam axis will increase the power density measurements.

The equipment used for measurements are as follows:

IFR Spectrum Analyzer IFR AN930
3 ft. of coax cable (measured loss of 1.8 dB)
Antenna Research Associates, INC Horn Antenna SWH-23 mounted a tripod

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Analysis of Measurements

The peak power measurements seen in table 1 cannot be directly related to the FCC Maximum Permissible Exposure (MPE). The duty cycle of the pulsed RF from the WSR-88D must be taken into account. Additionally, for General Population (or Uncontrolled) Exposure, the MPE is 1 mW/cm^2 time averaged over 30 minutes. For Occupational (or Controlled) Exposure, the MPE is 5 mW/cm^2 time averaged over 6 minutes.

Measurement Adjustments

The peak power density measurements must first be adjusted due to the duty cycle of the transmitted pulse. The WSR-88D is a pulsed doppler system. In its current configuration, it cannot transmit a continuous wave signal. The product of the transmitted pulse length to the Pulse Repetition Frequency (PRF) yields the duty-cycle adjustment. Under the PRF Charlie configuration, the longest duty cycle occurs when using a long pulse (4.5 us) under PRF 2 (446.43 Hz) and short pulse (1.5us) under PRF 8 (1282.05 Hz). This combination results in a duty cycle of .002. This is the maximum duty cycle the WSR-88D klystron is capable of.

The rotation and elevation of the antenna as defined by a particular VCP must also be considered to properly judge WSR-88D emissions against the FCC MPE levels. Each VCP is comprised of a number of elevation cuts at varying rotational rates. Due to the 1 degree beam width of the WSR-88D, elevation cuts above 0.5 degrees contribute a small fraction to the overall time-average and therefore will not be considered. The worst case time average will be seen when the WSR-88D is operating under VCP 31. As can be seen in Table 1, VCP 31 completes 2 elevation

VCP 31 (Long Pulse)

Elevation Angle	RPM	Waveform Type
0.5	0.84	CS
0.5	0.84	CD
1.5	0.84	CS
1.5	0.84	CD
2.5	0.84	CS
2.5	0.84	CD
3.5	0.84	CD
4.5	0.84	CD

Table 1 -VCP 31 Parameters

cuts at 0.5 degrees elevation and lasts 10 minutes. Therefore, during a 30 minute period of time and individual will be exposed 6 times to the duty-cycle averaged power density. At a rotational rate of 5 degrees per second, the duty cycle for VCP 31 is 1.2 seconds per 30 minutes for a ratio of $6.7(10^{-4})$.

Adjustment Effects

The maintenance software of the WSR-88D does allow the maintenance technician to transmit for up to 5 minutes while the antenna is stationary. Under these conditions, only the first adjustment (transmitted pulse duty cycle) applies. If an individual were 100 feet from the WSR-88D (the location of the highest peak power density measurement) while a maintenance technician commanded the WSR-88D to radiate, the radiation exposure would be over 2001 times below the FCC's Controlled (Occupational) Maximum Exposure Level and over 400 times below the FCC's Uncontrolled (General Population) exposure level (see figure 2).

Under operational conditions, both the duty cycle and dwell time adjustment apply. If an individual were 100 feet from the WSR-88D during VCP 31 (the worst case VCP as outlined above), the dose of radiation received would be over 3 million times less than the FCC's Controlled (Occupational) MPE and over 600,000 times less than the FCC's Uncontrolled (General Public) MPE (see figure 2).

Field measurements of the KOUN WSR-88D indicate that a WSR-88D on a 20 meter tower complies with FCC Maximum Permissible Exposure levels.

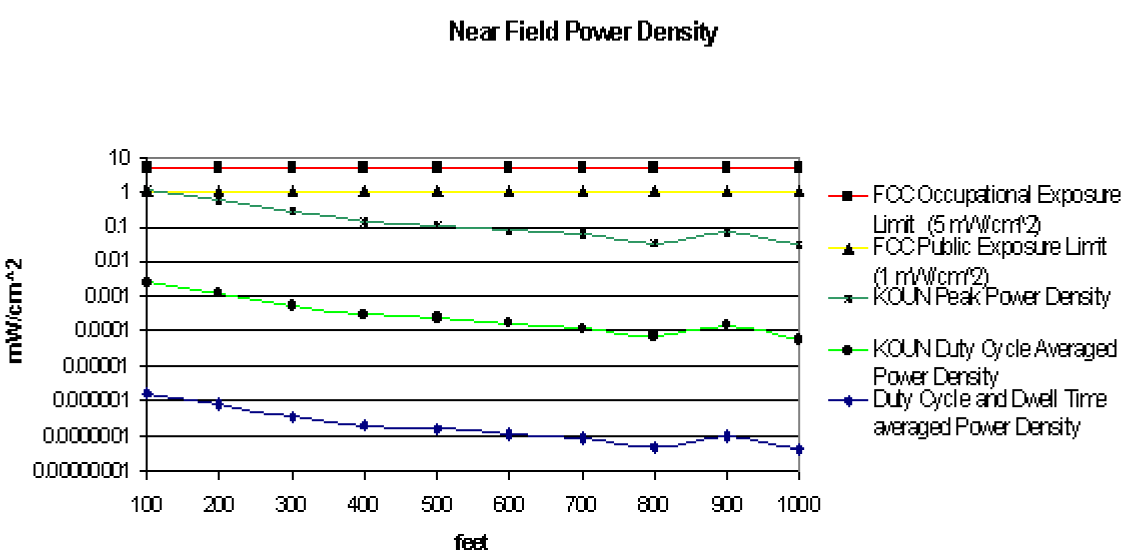

Figure 2 - Power Density Measurements (Actual and Averaged)

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Summary

Measurements taken from the KOUN WSR-88D indicate that RF exposure within 1000ft of the radar is significantly below the FCC Maximum Permissible Exposure Levels for both controlled (occupational) and uncontrolled (general population) environments.

It is important to note that the measurements were made under specific ranges and depression angles. It is expected that a tower of equal height with level terrain out to 1000ft would yield nearly the same results. Any variation in tower height will potentially lead to an uncorrelated variation in the power density measurements. The duty cycle and time averaging required to compare measurements to the FCC limits, suggests that it is unlikely that the currently fielded configurations of the WSR-88D would exceed FCC limits.

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References

[1] Lewis, Richard and Allen C. Newell, An Efficient and Accurate Method for Calculating and Representing Power Density in the Near-Zone of Microwave Antennas, NBSIR 85-3036, U.S. Department of Commerce, December 1985

[2] Next Generation Weather Radar (NEXRAD) Electromagnetic Radiation Hazard Survey , Report Number 89-40, 1839 Engineering Installation Group Engineering Division, Keesler AFB, MS, 16-18 Aug 1989.

[3] 47 CFR Parts 1, 2, 15, 24 and 97, Guidelines for Evaluating the Environmental Effects of Radiofrequency Radition, Federal Communications Commission, August 7, 1996

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Appendix A : Calculations

To calculate the Power Density:

$$P_d = \frac{10^{(P_r + Z_{line})/10}}{A_e}$$

P_d = Power Density (mW/cm^2)
P_r = Power Recieved[1] (dBm)
Z_{line} = Power loss of Coax cable at site frequency (dB)
A_e = Antenna Effective Aperture

For A_e:

$$A_e = \frac{G\lambda^2}{4\pi}$$

G = Numerical Gain of the measurement antenna
λ = Wavelength of radar (cm)

The gain of the horn antenna was found by interpolating the characteristics as indicated in the antenna's user manual (see Table 1). The italicized row was interpolated:

Frequency (Ghz)	Wavelength (m)	Gain (dB)	Gain	Ae (m^2)
2.6	0.11530	14.7	29.5120	0.031223735
2.705	*0.11091*	*15.27*	*33.7093*	*0.032995*
2.8	0.10707	15.8	38.0189	0.034682906
3.0	0.09993	15.5	35.4813	0.028196099

1 Measurements were peak values in dBm as measured by the spectrum analyzer.

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Appendix B: Collected Data

Equipment cable loss was measured at 1.8 dB at site frequency.

Range (ft) from KOUN	Pr (dBm)	Power at Output of Horn Antenna (mW)	Peak Power Density (mW/cm^2)	Duty-cycle Averaged Power Density (mW/cm^2)	Duty-cycle and Dwell time averaged Power Density (mW/cm^2)
100	24.35	412.098	1.249E+00	2.498E-03	1.674E-06
200	21.22	200.447	6.075E-01	1.215E-03	8.141E-07
300	17.76	90.365	2.739E-01	5.477E-04	3.670E-07
400	14.94	47.206	1.431E-01	2.861E-04	1.917E-07
500	14.00	38.019	1.152E-01	2.305E-04	1.544E-07
600	12.43	26.485	8.027E-02	1.605E-04	1.076E-07
700	11.22	20.045	6.075E-02	1.215E-04	8.141E-08
800	8.71	11.246	3.408E-02	6.817E-05	4.567E-08
900	11.84	23.121	7.007E-02	1.401E-04	9.390E-08
1000	8.08	9.727	2.948E-02	5.896E-05	3.951E-08